Biological control of Australian native plants, in Australia, with an emphasis on acacias

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Abstract

Australia's native flora is widely used in horticulture for amenity planting, windbreaks, garden ornamentals and revegetation programs. However, within Australia, native species utilised beyond their natural distribution have potential to naturalise and cause ecological harm in natural ecosystems with impacts similar to those caused by exotic plants introduced from overseas. In southern Australia, around 297 species of native plant are naturalised beyond their native range, including 41 species of *Acacia*. Loss of biodiversity through changes in biomass distribution, nutrient cycling, competition for resources, altered fire regimes and erosion patterns can be attributed to native plant invasions. Australian plants can be highly problematic overseas where many, particularly acacias, are subject to classical biological control. The principles of classical biological control can be applied to the suppression of weedy native plants in Australia, particularly priority trans-continental invaders, which include species of *Acacia, Billardiera, Hakea, Leptospermum, Melaleuca, Paraserianthes* and *Pittosporum*.

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Introduction

Australian native plants have been a source of fascination for horticulturists since their discovery by European explorers and settlers during the early colonisation of Australia (Elliot & Jones 1980; Cavanagh 1995, 2006). However, it was not until the 1950s, 180 years following Cook's maiden voyage, that Australian native plants surged in popularity with Australian gardeners, perhaps driven by recognition of their low-maintenance requirements, an increasing awareness and concern for the Australian flora, and a contribution to the search for national identity. At least 5,000 Australian native plants are recognised as horticulturally desirable (Elliot & Jones 1994), perhaps more if species used for revegetation and habitat restoration programs are included. *Acacia s.s.* (synonyms *Acacia* subgenus *Phyllodineae* and *Racosperma*, see Maslin 2008) Australia's largest plant genus (Maslin 2001) is a horticultural treasure trove with around 590 species recognised as suitable for cultivation (Elliot & Jones 1982), including taxa with a diverse array of ecological traits, canopy architecture, leaf shape, texture and colour, and floral features. Acacias were quickly taken into horticulture in Europe following colonisation of Australia, with *A. verticillata* (L'Her.) Willd. (Cavanagh 2006) being the first recorded species to flower in the northern hemisphere. A trans-global trade in Australian acacias soon followed, first inspired by horticultural interest, but largely driven later by agricultural-directed incentives including production of tannin, timber and pulp (Sherry 1971; Turnbull *et al.* 1998), fodder (Vercoe 1989; Thomson *et al.* 1994), food (Thomson 1992; Maslin *et al.* 1998), revegetation (Doran & Turnbull 1997) and erosion control (Shaughnessy 1980). Inevitably, Australian acacias are now naturalised in many locations including New Zealand, North and South America, Western Europe, Reunion Island, Britain and South Africa (Cadet 1981; Webb *et al.* 1988; Henderson 2001; USDA, NRCS 2006; Royal Botanic Gardens Edinburgh 2006) either as the result of intentional establishment programs, or as escapees from mostly well-intentioned horticultural activities. Many are now regarded as serious weeds where they threaten ecological, agricultural and water assets (Holm *et al.* 1979; van Wilgen *et al.* 2006). In Australia, broad-scale horticultural exploitation of acacias and other native plants has resulted in approximately 297 native vascular plants naturalising in habitats beyond their natural range, including 41 species of acacias (Table 1, J Hosking, M. Baker, D. Cooke, G. Keighery pers. comm. 2006). While many are weak adventives or marginally naturalised, others impact on threatened flora and fauna (Coutts-Smith & Downey 2006), or may have impacts equivalent to problematic foreign invasive plants.

Impact of invasive acacias and other native plants

The ecological and economic impact caused by invasion of native plants in Australia is documented by few case studies, despite increasing awareness of the potential of native plants as weeds. The impacts of invasive native plants can include disruption to ecological processes by accelerated biomass accumulation, reduced light penetration, increased nitrification, changed fire intensity and frequency, altered geo-morphological processes, hybridisation with congeners, which can lead to declines in species richness and abundance (Carr *et. al.* 1992). Many of these impacts are similar to the invasion of plants originating from other countries (exotic plants). However, quantified impact data on biodiversity values are only published for *Pittosporum undulatum* Vent. (Mullett & Simmons 1995; Rose & Fairweather 1997; Mullett 1999), *Leptospermum laevigatum* (Sol. ex Gaertn.) F. Muell. (Molnar *et al.* 1989; Lam & van Etten 2002) and *Acacia longifolia* (Andrews) Willd. (McMahon *et al.* 1996; Costello *et al.* 2000).

The ecological impacts of invasive Australian plants, particularly acacias, are best studied in South Africa, where 13 *Acacia* species are naturalised, and eight species cause widespread transformation of biological communities and ecological processes (Henderson 2001; Richardson & van Wilgen 2004). While the same scale of invasion and impacts are yet to be realised from native acacias within Australia, circumstantial evidence indicates that the potential is there. Rapidly expanding populations of *A. longifolia*, *A. dealbata* Link, *A. pycnantha* Benth. and *A. decurrens* Willd. in Western Australia; *A. cyclops* Cunn. ex Don in South Australia; and *A. saligna* (Labill.) W.L. Wendl., *A. baileyana* F. Muell. and *A. longifolia* in eastern Australia indicate broad-scale

Table 1. Number of Australian native plant species naturalised outside their native range in Australian States and Territories

State	Local native species[1]	Interstate native species[2]	Invasive Australian acacias[3]	Invasive exotic acacias[4]	References
Western Australia	42	61	18 (17%)	3	J. Hosking pers. comm. 2006, G. Keighery pers comm. 2006;
South Australia	13	41	10 (18%)	2	www.flora.sa.gov.au, D. Cooke, J. Virtue, J. Hosking pers. comm. 2006
Victoria	49	59	25 (23%)	1	Carr (2001), Flora Information System 2006, J. Hosking pers. comm. 2006
Tasmania	8	19	5 29%)	0	Buchanan (2005), M. Baker pers. comm. 2006, J. Hosking pers. comm. 2006
New South Wales	60	17	13 (17%)	1	J. Hosking pers. comm. 2006
Queensland	6	13	3(16%)	2	J. Hosking pers. comm. 2006
Northern Territory	5	4	1 (11%)	1	J. Hosking pers. comm. 2006

[1]Australian taxa native to the State, but naturalised beyond their pre-European distribution.

[2]Australian taxa native to other States or Territories.

[3]Native Australian *Acacia* taxa (proportion (%) of the total number of Australian taxa naturalised for each State or Territory).

[4]Naturalised non-Australian *Acacia* taxa. Doubtful or unsubstantiated records or those species with questionable native status have been omitted, possibly underestimating the numbers of naturalised taxa.

impacts may be inevitable without the implementation of appropriate control measures. In Australia, 43 native acacias are naturalised beyond their native range, in addition to three species of exotic acacias (these exotic species are in the former *Acacia* subgenus *Acacia*, that will become *Vachellia*, see Maslin 2008) naturalised in eastern and Western Australia (Table 1). In nearly all cases, invasions can be attributed to horticultural trade and the subsequent spread of plants from gardens, shelter-belts or amenity plantations. Many are currently weakly naturalised; others are aggressive invaders. The invasion of *A. longifolia* subsp. *longifolia* and *A. longifolia* subsp. *sophorae* (Labill.) Court and their intermediates across southern Australia is causing the disruption of a broad range of vegetation communities including coastal vegetation, heathlands, woodlands and lowland-foothill forests (Carr *et al.* 1992, McMahon *et al.* 1996; Costello *et al.* 2000; Emeny *et al.* 2006) is cause for concern. Declines in floristic and faunal biodiversity (McMahon *et al.* 1996, Clay & Schneider 2000; Costello *et al.* 2000; Rees & Paull 2000) are associated with invasions of *A. longifolia*. The recent rapid expansion of *A. longifolia* populations in the Grampians, Victoria, a centre of extraordinary floristic richness, is of concern for biodiversity management. *Acacia longifolia* subsp. *longifolia* may not be indigenous to the Grampians (Entwisle *et al.* 1996), while *A. longifolia* subsp. *sophorae* is almost certainly an introduced taxon there. Intermediates between the two taxa complicate the invasion scenario and management prospects. The impact of widespread and intense wildfires during January 2006 on population trends of these acacias in the Grampians needs to be carefully monitored.

Invasion patterns

Bruzzese and Faithfull (2001) eloquently describe three principal invasion patterns of weedy native plants in Australia: disturbance responders, range extenders and new bioregion invaders. In summary, disturbance responders increase in density within their natural distribution, primarily due to changed management regimes. Range extenders increase their geographic distribution beyond the boundaries of their natural range; and new bioregion invaders include many species that have increased their range by transgression of large-scale geographical barriers e.g. deserts, mountain ranges or seas. I specifically refer to these plants as trans-continental invaders. The categories of invasion are not mutually exclusive, for example, a trans-continental invader such as *Leptospermum laevigatum* in Western Australia, is both a disturbance responder and range extender in eastern Australia, and conversely for the Western Australian species, *Acacia saligna*.

While biodiversity impacts are associated with each of the three classes of invasion, the more serious and intractable problems are usually associated with range extensions and invasions into new bioregions, particularly the latter where invaders often experience reduced herbivory pressure from phytophagous agents. Casual observations suggest this is the case for a broad range of invasive native plants including *A. longifolia, A. saligna, A. dealbata, A. pycnantha, L. laevigatum, Billardiera fusiformis* Labill., *B. heterophylla* (Lindl.) L. Cayzer, *Paraserianthes lophantha* (Willd.) I.C. Nielsen subspecies *lophantha* and *Hakea drupacea* (C.F. Gaertn.) Roem., perhaps contributing to their success as weeds, but quantified comparisons of host fitness and herbivory loads between indigenous and introduced distributions are sadly lacking.

Trans-continental native invaders seem to exhibit sigmoidal invasion curves, typical of many exotic invasive plants, indicating a release from biological or environmentally-induced constraints. Perhaps the best example of this is the colonisation and expansion of the Western Australian endemics *Billardiera heterophylla* and *B. fusiformis*, which are now scattered over large areas of eastern Australia (AVH 2006). In eastern Australia, these twining shrubs readily invade natural vegetation communities and can form dense, almost impenetrable thickets, clearly reducing biodiversity values and often limiting recreational and utilisation options for native vegetation. Native plant invaders that increase their range without transgressing large biological barriers (range extenders), are often accompanied by herbivorous agents, typically invertebrates that may limit the colonisation capacity and rate of spread of these weed species. An example of this is the presence of herbivores on *A. baileyana* in its invaded range in eastern Australia, which includes the seed-feeding curculionid *Melanterius maculatus* Lea, the flower-galling pteromalid *Perilampella ?hecateus*, flower and bud-galling cecidomyiids (*Asphondylia* and *Dasineura* spp. (Adair *et al.* 2000), sap-sucking psyllids (Yen 2002) and a range of canopy-deforming fungi, including *Uromycladium notabile* McAlpine (Marks *et al.* 1982). These organisms can have a debilitating impact on the health of *A. baileyana* and all are likely to be indigenous in the host's natural range around Cootamundra, New South Wales, although movement of organisms from related acacias onto *A. baileyana* in its introduced range may also have occurred.

Fortunately, the vast majority of acacias currently in horticulture have not been recorded as naturalised, but methodologies designed to predict future invaders or safe taxa, for that matter, from this pool of species tend to be based on invasion histories or remain largely untested. It is difficult to visualise how risk assessment procedures, such as the analytical hierarchical process (AHP) (Weiss & McLaren 2002), could be sufficiently sensitive to predict new invasive acacia taxa, where many of the biological and ecological characteristics are so similar within the genus.

Control of invasive native plants

As invasive native plants are increasingly recognised as problematic in natural vegetation (Carr *et al.* 1992; Keighery 1999; Carr 2001; Groves 2001; Low 2001) many are subject to suppression programs to protect biodiversity values. Control options vary according to life-form, susceptibility, risk of non-target damage, ease of implementation, size of infestation and outcome targets. Control options for native plants include the use of herbicides, planned fire, grazing, manual removal, biological control, and integrated methods, including the highly effective method (for some woody plants) of 'rolling' infestations with heavy equipment, then burning after a period of drying (Muyt 2001). This paper focuses on the potential for biological control of Australian native plants, with a focus on Australian acacias.

Biological control

The concept of biological control of native plants in Australia commenced in 1901 with an augmentative

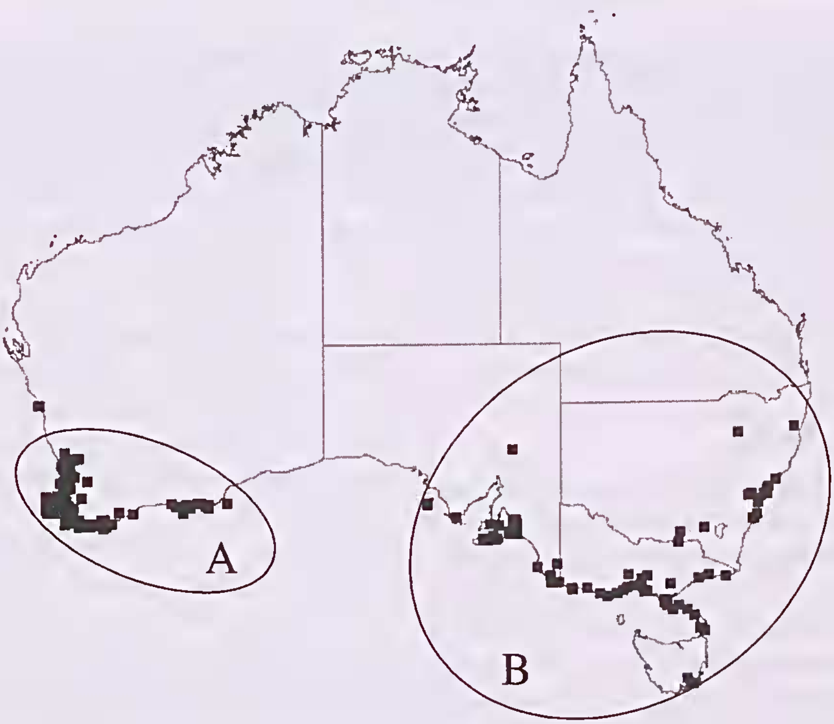

Figure 1. Distribution of Paraserianthes *lophantha* subsp. *lophantha* in Australia. A. indigenous range, B. naturalised range, although occurrences on the Furneaux Islands of Bass Straight may be indigenous (Harris 2001) and warrant investigation for clarification.

approach developed for the cosmopolitan perennial sedge *Cyperus rotundus* L. (Cyperaceae) by translocating the nut-grass coccid *Antonina australis* Green (Wilson 1960). This was followed in the 1990s by biocontrol of the disturbance-responders *Cassinia arcuata* R. Br., *C. laevis* R. Br. and *C. quinquefaria* R. Br. (Asteraceae) using native scale insects (Campbell & Wykes 1992; Holtkamp & Campbell 1995). Subsequent programs then targeted *Eremophila* spp. and *Dodonaea viscosa* Jacq. with the distribution of a coccid and eriophyiid, respectively (Sparkes & Robinson 1997; Sparkes 2000). More recently, the development of the classical biological approach for a range of native invasive plants is advocated including pathways for potential implementation (Adair 1995, Bruzzese & Faithfull 2001).

Eight species of Australian acacias are primary targets for classical biological control in South Africa using Australian organisms. After more than 30 years of research, in some cases, considerable success has been achieved in the biological suppression of *A. longifolia*, *A. cyclops*, *A. saligna*, *A. pycnantha* and *A. melanoxylon* R. Br. using a range of organisms including gall-

Table 2. Potential native plant targets (bold) for biological control in Western Australi

Feasibility	Ecological impact		
	High	Medium	Low
High	***Acacia dealbata, A. decurrens, A. langifalia, A. pycnantha, Leptaspermum laevigatum***	***A. baileyana, A. mearnsii, A. melanaxylon, A. flaribunda, A. podalyriifolia, Pittasparum undulatum***	*Acacia iteaphylla, A. elata, A. mallifolia, Brachychitan populneus, Hibiscus diversifalius, Acaena navae-zealandiae*
Medium	*Hydrilla verticillata*	*Melaleuca armillaris, Phragmites australis, Leptospermum ratundifalium*	*Bacopa monnieri, Callitris glaucophylla, C. columellaris, Casuarina spp., Dadanaea viscosa, Solanum aviculare, S. laciniatum*
Low		*Cyathea caaperi, Eucalyptus maculata, E. cladocalyx, Dennstaedtia davalliades, Hypalepis rugulosa, Vallisneria americana*[1]	*Aristida ramosa, Banksia canei, Eucalyptus spp., Juncus usitatus, Patamagetan crispus, Rumex brawnii*

[1]Current taxonomic revision of the genus may alter categorisation of this species.

Species in bold are priority targets, the remainder have a low probability for success or are unusable as targets

Table 3. Potential native plant targets (bold) for biological control in eastern Australia

Feasibility	Ecological impact		
	High	Medium	Low
High	***Billardiera heterophylla, B. fusifarmis***	***Acacia saligna, Hakea drupacea, Paraserianthes laphantha spp. laphantha***	*Aganis spp., Acacia cyclaps, A. iteaphylla, A. paradaxa, A. pulchella, A. pycnantha, A. rastellifera, Callistachys lancealatum, Dryandra farmasa*
Medium	*Hakea elliptica, Melaleuca diasmifolia*	*Hakea laurina, Melaleuca nesaphila*	*Callisteman rigidulus, Eucalyptus astringens, E. canferruminata, E. gomphocephala, E. kandinensis, E. accidentalis*
Low	*Melaleuca hypericifalia*		*Astartea heteranthera, Cladium procerum, Kennedia nigricans, Melaleuca incana, M. viminea*

Table 4. Potential biological control agents for native trans-continental invaders in Australia

Species	Common name	Target region	Family	Species	Mode of action	Conflict of interest[1]
Leptospermum laevigatum	Coast Tea-tree	WA	Cecidomyiidae	*Dasineura* sp. 1	Bud galler	L
			Cecidomyiidae	*Dasineura* sp. 2	Bud galler	L
			Gracillariidae	*Parectopa thalassias*	Leaf miner	M
			Coccoidae	Undetermined	Sap sucker	H
			?Eriophyiidae	Undetermined	Twig deformer	M
Acacia longifolia	Long-leaf Wattle	WA	Pteromalidae	*Trichilogaster acaciaelongifoliae*	Shoot galler	M-H
			Curculionidae	*Melanterius ventralis*	Seed feeder	L
			Cecidomyiidae	*Dasineura acaciaelongifoliae*	Flower galler	L
Acacia dealbata	Silver Wattle	WA	Curculionidae	*Melanterius maculatus*	Seed feeder	L
			Pteromalidae	*Perilampella ?hecateus*	Flower bud galler	M
			Cecidomyiidae	*Dasineura pilifera*	Flower galler	L
			Cecidomyiidae	*Dasineura sp. nov.*	Pouch galler	L
			Pteromalidae	Undetermined	Leaf rachis galler	L
			Uredinales	*Uromycladium tepperianum* (biotype)	Stem/leaf/flower galler	H
			Cecidomyiidae	?*Cecidomyia* sp.	Flower galler (Red Plush Gall)	L
Acacia decurrens	Green Wattle	WA	Cecidomyiidae	*Dasineura pilifera*	Flower galler	L
			Curculionidae	*Melanterius maculatus*	Seed feeder	L
			Uredinales	*Uromycladium tepperianum* (biotype)	Stem/leaf/flower galler	H
Acacia mearnsii	Black Wattle	WA	Curculionidae	*Melanterius maculatus*	Seed feeder	L
			Cecidomyiidae	*Dasineura rubiformis*	Flower galler	L
			Cecidomyiidae	*Dasineura sp. nov.*	Flower galler	L
			Cecidomyiidae	*Dasineura fistulosa*	Flower galler	L
			Cecidomyiidae	*Asphondylia* sp.	Bud galler	L
			Uredinales	*Uromycladium tepperianum* (biotype)	Stem/leaf/flower galler	H

Species	Camman Name	Target Region	Family	Species	Made af Actian	Conflict of Interest[1]
Acacia melanaxylan	Blackwoad	WA	Curculianidae	*Melanterius acaciae*	Seed feeder	L
			Cecidamyiidae	*Dasineura furcata*	Flower galler	L
Acacia pycnantha	Galden Wattle	WA	Pteramalidae	*Trichilagaster signiventris*	Shaat galler	M
			Uredinales	*Uramycladium tepperianum* (biatype)	Stem/leaf/flawer galler	H
Acacia padalyriifalia	Maunt Margan Wattle	WA	Eurytamidae	*Bruchaphagus* sp.	Seed feeder	L
Pittasparum undulatum	Sweet Pittasparum	WA	Agromyzidae	*Phytaliriamyza pittasparaphylli*	Leaf miner	M
			Phlaeathripidae	*Teuchathrips pittaspariicala*	Sap sucker	M
			Chrysamelidae	*Lampralina aeneipennis*	Defaliatar	M
			Psyllidae	*Triaza vitearadiata*	Sap sucker	M
			Cerambycidae	*Strangylurus tharacicus*	Waad borer	M
Billardiera heteraphylla, B. fusifarmis	Blue-bell Creeper	VIC, SA,TAS, ACT	Cecidamyiidae	*Asphandylia* sp.	Bud/shaot galler	M
			Cecidamyiidae	?*Lasiaptera* sp.	Shaot-tip galler	M
			?Eriaphyiidae	Undetermined	Stem defarmer	H
Acacia saligna	Part Jacksan Wattle	VIC, NSW	Curculianidae	*Melanterius campactus*	Seed feeder	L
			Uredinales	*Uramycladium tepperianum* (biatype)	Stem/leaf/flawer galler	H
			Eriaphyiidae	*Aceria acaciflaris*	Shaat deformer	M
				Aceria burnleyae	Inflarescence defarmer	
Paraserianthes laphantha subspecies *laphantha*	Cape Leeuwin Wattle	VIC, TAS, NSW	Curculianidae	*Melanterius servulus* (biatype)	Seed feeder	L
			Uredinales	*Uramycladium tepperianum* (biotype)	Stem galler	M
Hakea drupacea	Sweet Hakea	VIC, TAS, NSW	Cerambycidae	*Aphanasperma* sp.	Seed Feeder	?L
Acacia cyclaps	Red-eye Wattle	VIC, SA	Curculianidae	*Melanterius servulus*	Seed feeder	L
			Cecidamyiidae	*Dasineura dielsi*	Flawer galler	L
			Cecidamyiidae	*Asphandylia* sp.	Bud galler	L

[1] H= high risk of conflict of interest, M= medium risk, L= low risk.

forming cecidomyiids and pteromalids, seed-feeding curculionids, and a gall-inducing pathogen (Olckers & Hill 1999). The accumulation of knowledge on the biology and taxonomy of organisms associated with Australian acacias through biological control programs has been of considerable mutual benefit to both South Africa and Australia, where the legacy is contributing to better natural resource management. Other nations, such as Portugal, now plan the implementation of biological control of Australian acacias (Sheppard *et al.* 2006).

In Australia, invasive native acacias are not subject to intentional biological control. However, in the case of trans-continental invaders, where natural and introduced populations are separated by large and often hostile geographical barriers, there is potential for the utilisation of classical biological control principles to develop suitable control programs. Australian acacias often support rich phytophagous biotas (New 1984), with many species exhibiting high levels of host specificity (Kolesik *et al.* 2005, Yen 2002), a mandatory requirement for acceptable biocontrol. Those organisms that are also capable of disrupting growth or reproductive patterns and themselves are constrained by similar geographical barriers as their host, are candidates for biological control within Australia. As natural enemies (parasitoids, predators and pathogens) frequently influence the ecology of phytophagous organisms on native plants, the introduction of phytophagous organisms across biological barriers without their specialist natural enemies may accrue population increases of the phytophage in the introduced range by the creation of enemy-free or enemy-reduced space, thus contributing to the suppression of the target weed. However, several factors could mitigate against the success of such an approach. Australian acacias appear to vary considerably in the richness of their phytophagous biota, with some species apparently supporting meagre faunas, therefore offering limited opportunities for the selection of potential biocontrol agents. Natural enemies with broad geographical distributions could handicap the creation of enemy-free space in the introduced range of invasive plants and prevent the build-up of super-populations of the selected phytophage. In addition, the progressive range extension of invasive native plants can reduce the distance between indigenous and introduced distributions, weakening biological barriers (e.g. figure 1), therefore increasing the potential for natural enemies to undertake trans-continental dispersal, via the colonisation of naturalised or ornamental populations of the host into the main invasion zone. Furthermore, with readily accessible domestic travel routes within Australia and high trans-continental movement rates, the risk of accidental or deliberate movement of natural enemies associated with biological control agents for native plants would be higher within Australia compared to biocontrol programs operating overseas.

Invasion of eastern Australian cecidomyiids in Western Australia - proof of concept

The gall-forming cecidomyiid *Dasineura rubiformis* Kolesik is restricted to a small group of *Acacia s.s.* section *Botrycephalae* species indigenous to eastern Australia, with *A. mearnsii* De Wild. as the principal host (Kolesik *et al.* 2005). Eggs are laid on or around the ovary of open flowers, which soon become swollen and distorted forming small basal chambers used for larval development. Affected ovaries fail to produce seeds. Larvae remain within the gall until June-August then emerge to pupate in the soil beneath the host tree. Adults emerge at the onset of flowering in September-November and are very short lived. In eastern Australia, the insect is mostly heavily parasitised by micro-hymenoptera and gall densities are usually low, sporadic and have little impact on overall fruit production. This is in contrast to populations in Western Australia, where super abundant densities are common, widespread and appear regularly on *A. mearnsii*. This is largely attributed to reduced parasitoid pressures (Adair 2004). In Western Australia, *A. mearnsii* is non-indigenous and weakly invasive. Entomological surveys on *A. mearnsii* and other acacias in Western Australia by South African scientists in the 1980s did not detect the presence of *D. rubiformis* (M. van den Berg unpublished data), suggesting that colonisation occurred post-1980, but the exact date and mode of entry into Western Australia cannot be determined. Super-galling by *D. rubiformis* significantly reduces seed production of *A. mearnsii* in Western Australia (Adair 2004) and undoubtedly contributes to the suppression of this plant in the south-west region. As no indigenous Western Australian acacias are hosts to *D. rubiformis*, the insect is an exemplary case of the potential for biological control of invasive trans-continental plants. Two other eastern Australian cecidomyiids, *D. pilifera* Kolesik and *Dasineura* sp. (Pouch Galler), occur on *A. dealbata, A. decurrens* and *A. baileyana* in Western Australia and while density levels appear to be relatively low, no data are available on population trends to determine likely impacts of these insects.

Selection of native plants as targets and implementation of biological control

Classical biological control techniques mostly require substantial investment of resources and human effort (Harley & Forno 1992). Accordingly, targets selected for biological control require favourable cost:benefit ratios and reasonable probabilities of success, and should be directed at invasive species that cause, or have the potential to cause, serious ecological or economic harm. While quantitative data are absent for all of these criteria for native invasive plants, prospective biocontrol targets can be identified using a qualitative assessment process. This assessment would be based firstly on characteristics of the plant: invasiveness, disruption to ecological processes, impact on biodiversity values, and rate of spread. Secondly, the potential for success based on availability of host specific organisms and their likely impact, the degree of bio-geographic segregation in the introduced range, and the potential for conflict of interest would be taken into account. Using the process outlined above, potentially suitable targets for biological control have been identified: 11 species in Western Australia (table 2) and five species in eastern Australia (table 3). The absence of indigenous *Botrycephalae* in Western Australia contributes substantially to their suitability as targets for biocontrol in that state. In addition, as most Western Australian acacias are medium to small shrubs, and rarely trees, invasive *Botrycephalae* are likely to have profound ecological impacts in natural ecosystems, therefore further increasing their suitability as biocontrol targets.

Fortuitously, the phytophagous faunas associated with many Australian trans-continental invaders have been documented to varying degrees, largely the result of biocontrol prospecting undertaken by South African biologists (van den Berg 1978, 1979, 1980a,b,c, 1982a,b,c; unpublished data). Therefore, potential biocontrol agents can be identified and the level of potential conflict of interest assessed based on mode of feeding of the respective agent (table 4). However, for several invaders, namely *Hakea drupacea, Acacia floribunda* (Vent.) Willd. and *Acacia podalyriifolia* Cunn. ex Don, few phytophagous records are available and exploratory work is required to identify potential agents for these species.

Australian horticultural industries utilise native trans-continental invasive plants, mostly as ornamental plants for domestic or international trade, therefore attempts to undertake biological control could establish conflicts of interest with these industries and their clients. Procedures for resolving conflicts of interest associated with the introduction of biological control agents are available through the *Biological Control Act* 1984 (BCA). The BCA was developed to deal with organisms exotic to Australia, but it could also be applied to native organisms, although this remains untested. In situations where the target plant has no economic value or where the potential agent generates low and resolvable levels of conflict, formal use of the BCA may not be required, a desirable outcome as utilisation of the BCA can incur considerable costs (McLaren *et al.* 2006). Many of the conflicts of interest potentially associated with biological control of Australian native plant invaders could be resolved by declaration of the invader under State or Territory noxious weed legislation, even if the declaration only restricts the sale, transport or trade of the listed species. Currently, few Australian native plants (*Acacia baileyana, A. paradoxa, Cassinia arcuata, Ceratophyllum demersum* L., *Hydrilla veriticillata* (L.f.) Royle, *Pittosporum undulatum, Sclerolaena birchii* (F. Muell.) Domin, *Typha* spp.) are declared as weeds (Thorpe & Wilson 2006) on the basis of their ecological damage. The development of case studies to explore the natural enemy complexes of native invasive plants in the context of development of biological control is advocated (Bruzzese & Faithfull 2001). An additional advantage of such an approach would be to explore the legislative frameworks and procedures that would enable the development of classical biological control of Australia's trans-continental invaders. This important process would include development of protocols for host specificity testing and evaluation of results. The suggestion of *Billardiera* (*Sollya*) *heterophylla* and *L.*

laevigatum as candidate species (Bruzzese & Faithfull 2001) for biological control is considered the only plausible method for landscape-scale suppression of these weeds. However, the invasive *Acacia* species identified in this paper should also be considered. Collaborative research arrangements between relevant Western Australian and eastern Australian government authorities, under the auspices of the Australian Weeds Committee, could expedite the development of this concept.

Future trends

The demand for horticultural novelties contributes to the introduction of new native plants into Australian horticulture. The rate of plant naturalisations in Australia is increasing (Groves 1997) and current trends suggest that more Australian native plant species will establish as problematic environmental weeds. The adoption of early intervention control strategies could help alleviate this scenario, if native plants are taken into consideration as potentially problematic weeds. However, careful consideration to the native plant species utilised by Australian horticultural industries could contribute even more to the prevention of new and emerging weedy native plants. While our ability to predict new weeds with no previous invasion history is weak, a precautionary approach to the adoption and promotion of non-indigenous native plants should be supported. The same principle needs to be applied to the promotion of Australian plants, particularly acacias, in overseas markets, where the global distribution of species for fodder, fuel, fibre and timber, particularly in less developed countries, may ultimately cause problems worse than those they were intended to solve.

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